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Evaluation of Physicochemical and Sensory Properties of Gruel from Maize-Millet Composite Flours Fortified with Defatted Soybean Flour

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Abstract

The proximate composition, physicochemical, and sensory characteristics of custard formulated from maize (MZF) and millet flours (MLF) with soybean flour (SBF) were studied using Minitab 2 x 3^n factorial design. The results showed that the protein content of the formulations increased steadily with soybean flour supplementation from 10.65 percent in 90:10 (MF: SF) to 17.16 percent in 50:50 (MF: SBF) samples, while carbohydrate decreased and ranged from 77.23 to 88.38 percent; moisture (5.41 to 12.02 percent); protein (3.87 to 7.23 percent); fiber (0.01 to 0.16 percent); and fat (0.01 to 0.76 percent). The formulation's energy content declined as soybean flour fortification rose from 360.50 kJ at 50:50 (CS: SF) to 373.78 kJ at 90:10. (CS: SF). The sensory evaluation of custard formulation samples reconstituted into gruel with boiling water indicated no significant difference ($p > 0.05$) from the control.

Keywords: *Custard; Millet Flour; Soybean Flour; Maize; Fortification*

Introduction

In many parts of the world, maize is considered a stable food. After rice and wheat, it is one of the world's third most important crops [1]. The kernel, which is the edible and healthy part of the plant, contains vitamin C, vitamin K, vitamin B_1, vitamin B_2, vitamin B_3, vitamin B_5, vitamin B_6, folic acid, selenium, N-p-coumaroyl tryptamine and N-ferrulyltryptamine [2]. Aside from the primary foods, millet is one of the cereals, along with wheat, rice, and maize. They are the primary food source for millions of people, especially those living in the world's hot, dry areas. Millets are grown primarily in marginal areas under agricultural conditions where major cereals fail to yield substantially [3]. Their ability to thrive under adverse weather conditions like limited rainfall makes it one of the major staples of underdeveloped countries. For millions of people in Africa, millets are their primary source of protein and energy. Numerous health benefits and nutritional claims have been made for millet [4]. Millets are unique among cereals because of their richness in calcium, dietary fiber, polyphenols, and protein [5]. Millet generally contains significant amounts of essential amino acids (methionine and cysteine) and is also higher in fat than maize, rice, and sorghum [6].

Soybean (Glycine max) is a highly nutritious and reasonably priced plant protein source. Its nutritional content and functional qualities can enhance the diets of millions of people, especially the poor and low-income earners in developing countries [7]. Ikegwu., *et al.* [8]

advocated using legumes as a supplement to cereals due to the provision of an adequate amount of lysine for growth and maintenance. Soybean is rich in protein (40%) and fats (20%) and contains moderate quantities of tryptophan and threonine [9]. Commercially, its seeds are utilized for human consumption, cattle feed, and oil production [10]. Nutritionally, soybean protein resembles animal protein more closely than other vegetable proteins from oilseeds and legumes [11]. According to Pusty., *et al.* [12], soybeans are a major ingredient in food products made from cereals and tuber crops due to their functional qualities and high nutritional content. Adding soybean flour to composite flour made of maize and millet may change the physio-chemical properties. As a legume, soybeans have a high protein and fat content with a relative amount of lysine, tryptophan, and threonine [8]. Furthermore, it is advocated that soybeans could be an excellent supplement to cereals due to the content of an adequate amount of lysine, which is lacking in cereals, for proper nourishment of the body [13].

Maize and millet could be used for the production of gruels referred to as custard. Custard is a cornstarch-based porridge with a delicate texture with the addition of salt, flavoring, and colorant agents. At the same time, egg yolk solids, vitamins, and minerals are optional ingredients, although eggs could serve as a source of protein [14]. Custard powder can be used as an infant supplement, eaten as breakfast, and provided to the sick [15]. The improvement of the nutritional status of custard by the addition of vegetable proteins from oilseeds and legumes that are cheap and readily available, such as cowpea, Soybean, and pigeon pea, is vital as the porridge is a carbohydrate food product [16].

However, due to poverty in many developing countries, especially in sub-African countries, many people eat custard without milk or eggs, which depletes proteins and adds to nutritional issues. Many people have been linked to malnutrition [17]. As a result, it could be significant to add protein to millet-based products. This work was conceived to formulate custard products from locally available raw food materials other than corn, and to evaluate the quality of the produced product when fortified with soybean flour.

Materials and Methods

Source of raw materials

The research was conceived to formulate a complementary food product from white maize (*Zea mays*), pearl millet (*Pennisetum glacum*), and Soybean (*Glycine max*) purchased from Cereal Research Institute, Badeggi, Niger State, and egg yellow and vanilla flavor was obtained from a well-known food chemical store in Lagos State. The custard was purchased from Eke Awka market in Anambra State, Nigeria for the control sample.

Processing of raw materials

Processing of corn starch

Two kilograms of clean maize grains were weighed and crushed (attrition mill) into grits. The grits were soaked in tap water for 24h with 6-h water changes to prevent fermentation. After steeping, the grits were filtered or sieved (muslin cloth) and sedimented for 3h. After filtering and dewatering, the cabinet dryer dried the starch and filtered sediments (650°C, 6h). After drying, the starch was milled with the aid of attrition mill (SK-30-SS, New York) and sieved through a 400-mesh scale. After processing, the cornstarch was wrapped in polyethylene bags for custard making.

Processing of defatted soybean flour

Soybean seeds (2 kgs) without stones, sticks, or leaves were weighed, washed, dried in the cabinet dryer (650ºC, 1h), and soaked in tap water for 24 hours. After soaking, the seeds were cleaned, dehulled manually, boiled (100˚C, 30 min), and cabinet-dried (65˚C, 12h). The

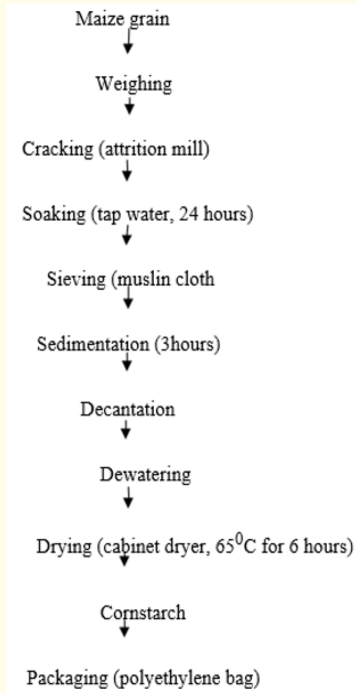

Figure 1: *Flow chart for cornstarch production.*

flour was defatted in a Soxhlet extractor with 100 ml of n-hexane for 8 hours after milling the dried seeds. The defatted soybean flour was then cabinet-dried (680°C, 2h), cooled, milled (SK-30-SS, New York), and sieved through a 400-mesh sieve. After defatting, the soybean flour was wrapped in plastic bags for custard making.

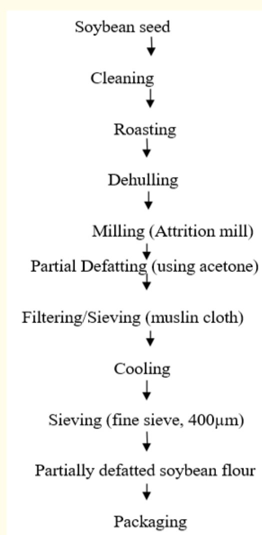

Figure 2: *Flow chart for production of defatted soybean flour.*

Processing of millet flour

Two kgs of sorted millet grains were cleaned and soaked in tap water. The soaked grains were kept at room temperature (37°C) for 24h. After washing, the water was drained, and the grain was rinsed with 500 ml of water and oven-dried at 80°C for 3h. Then, the grains were milled (dry mill) and sieved with a 400-mesh scale. The millet flour produced was packaged in sealed polyethylene bags to blend and prepare custard formulation.

Figure 3: *Flow chart for production of millet flour.*

Experimental design

The research used Minitab software on a 2 x 3^n factorial to obtain eight samples. The design of the experiment is shown in table 1. The regression equation was obtained using the interaction between the samples as shown: $Y_1 = a + X_1 + X_2 + X_3 + X_1 X_2 + X_1 X_3 + X_2 X_3 + X1X_2X_3$.

Sample Runs	Cornstarch	Millet Flour	Defatted soybean flour
1	70	10	5
2	70	30	5
3	70	30	10
4	100	10	10
5	100	10	5
6	70	10	70
7	100	30	10
8	100	30	5
9	Commercial Product (Check)		

Table 1: *Experimental design.*

Preparation of custard formulation

The cornstarch-millet-soybean composite flour blends were formulated by using different ratios of the cornstarch (CS)-millet flour (MF) composite, and then fortified with Soybean (SF) at 5 - 10% in a Kenwood mixer (model A900) for 25 - 30 minutes. Additional ingredients such as 15% egg yellow, 10% vanilla flavor, and 20% salt were added to each flour blends and then blended in a Kenwood mixer (model A220) for 10 min. The formulated custard products were sealed in polyethylene bags and stored at room temperature until needed for laboratory analysis. A formulation of 100% cornstarch flour was also made. The millet-maize starch-enriched custard powder production flowchart are shown in figure 4.

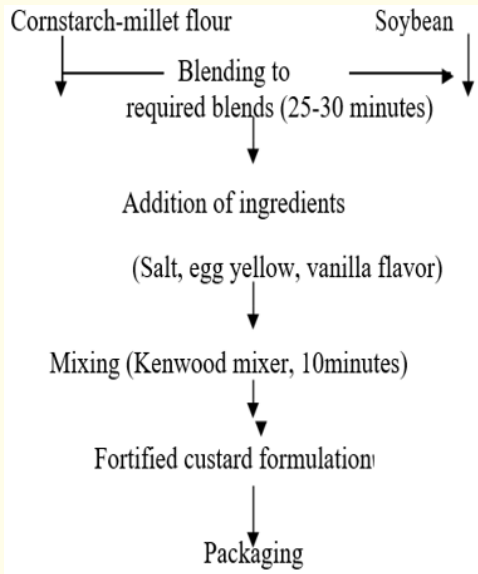

Figure 4: *Flowchart of millet-maize starch enriched custard powder production.*

Chemical analysis of samples

Standard procedures were used to estimate moisture, ash, crude fiber, fat, protein, and carbohydrate content in enhanced custard samples [18].

Physicochemical properties

Functional and rheological properties were carried out on the custard samples, such as least gelation concentration [19], water absorption capacity [20]; bulk density, swelling power, and solubility [20] and pasting properties.

Sensory evaluation

The sensory preference of the maize-millet gruel was assessed using 20 semi-trained panelists from the Department of Food Science and Technology, Nnamdi Azikiwe University Awka. The samples were prepared and served in a stainless steel plates to the panelists involving both males and females using 9-Point Hedonic Scale, where 1 denotes "dislike extremely", while 9 denotes "like extremely" for assessment based color, taste, aroma, flavor, texture and overall acceptability. The mean scores were subjected to Analysis of Variance ($p < 0.05$) to determine the degree of preference for samples. The panelists wilfully consented to test the samples in the Food Science and Technology Laboratory of Nnamdi Azikiwe University Awka, without recourse to the University Ethics Committee Approval.

Statistical analysis

The work used a 2 x 3^n factorial design. Data was analyzed using One-Way-Anova. Minitab 17.0 calculated the regression coefficient. The least significant difference was used to separate the means, and 5% significance was accepted.

Results and Discussion

Proximate composition

The proximate compositions of cornstarch-millet and soybean-enriched custards are shown in table 2. The moisture percentage of the custard formulations varied significantly ($p < 0.05$) from 5.41 to 12.02 percent. The considerable discrepancies ($p < 0.05$) in moisture content may be due to factors such as flour samples' formulation variable drying rates. The composite flour moisture content varied because the flours had diverse chemical structures, which altered drying speeds. Surprisingly, the sample with the ratio 100:30:10 had abnormally high moisture content (12.02%). This abnormality could be a processing error or malfunction of the equipment which could have introduced an error. However, the regression analysis showed the interaction effect of substituting the custard formulations. With an R^2-value of 99.89% and R-adjusted 99.80%, it could be asserted that the increased addition of cornstarch led to a decrease in moisture content, while millet and soybean flours positively affected the moisture content of the products.

Sample Runs C:M:S	Moisture (%)	Ash (%)	Protein (%)	Fibre (%)	Fat (%)	Carbohydrate (%)
70:10:5	$6.95^{d} \pm 0.08$	$2.49^{b} \pm 0.01$	$5.30^{c} \pm 0.07$	$0.01^{b} \pm 0.01$	$1.15^{ab} \pm 0.21$	$83.37^{e} \pm 0.03$
70:30:5	$7.99^{c} \pm 0.01$	$2.51^{b} \pm 0.01$	$4.63^{f} \pm 0.04$	$0.01^{b} \pm 0.00$	$1.50^{a} \pm 0.01$	$85.13^{d} \pm 0.04$
70:30:10	$7.97^{c} \pm 0.04$	$2.99^{a} \pm 0.01$	$4.96^{d} \pm 0.10$	$0.01^{b} \pm 0.00$	$0.76^{abc} \pm 1.05$	$77.23^{g} \pm 0.04$
100:10:10	$9.83^{b} \pm 0.25$	$2.02^{c} \pm 0.02$	$7.02^{b} \pm 0.01$	$0.03^{b} \pm 0.01$	$0.49^{bc} \pm 0.01$	$84.72^{d} \pm 0.03$
100:10:5	$5.78^{f} \pm 0.04$	$2.51^{b} \pm 0.01$	$3.87^{g} \pm 0.02$	$0.01^{b} \pm 0.00$	$0.01^{c} \pm 0.00$	$87.32^{c} \pm 0.04$
70:10:10	$5.59^{e} \pm 0.01$	$1.50^{d} \pm 0.01$	$3.92^{g} \pm 0.03$	$0.05^{b} \pm 0.00$	$0.05^{c} \pm 0.00$	$80.93^{f} \pm 0.06$
100:30:10	$12.02^{a} \pm 0.02$	$1.51^{d} \pm 0.01$	$7.23^{a} \pm 0.14$	$0.16^{b} \pm 0.18$	$0.50^{bc} \pm 0.00$	$83.45^{e} \pm 0.64$
100:30:5	$6.50^{d} \pm 0.01$	$1.51^{d} \pm 0.01$	$4.81^{e} \pm 0.14$	$0.02^{b} \pm 0.02$	$0.01^{c} \pm 0.01$	$88.38^{b} \pm 0.04$
*Check	$5.41^{g} \pm 0.01$	$0.71^{e} \pm 0.09$	$1.31^{h} \pm 0.01$	$1.52^{a} \pm 0.02$	$0.82^{abc} \pm 0.02$	$90.27^{a} \pm 0.02$

***Table 2**: Chemical composition of custard samples from maize-millet fortified with soybean.*

**Check = Commercial Custard Product.*

C = Cornstarch; M = Millet Flour; S = Defatted Soybean Flour.

Furthermore, the interaction of cornstarch and millet flour positively influenced the moisture content of the samples, but the cornstarch and soybean flour interaction was negatively correlated. On the other hand, millet-soybean flour interaction positively influenced the moisture content of the samples. The interaction of the three individual flours (corn starch, millet flour, and defatted soybean flour) decreased the moisture content of the flours as represented by the regression equation: ($MC = -2.511X_1 + 0.384X_2 + 2.726X_3 + 0.036X_1X_2 - 0.951X_1X_3 + 1.224X_2X_3 - 0.619X_1X_3 - 0.619X_1X_2X_3$).

The regression analysis of the influence of the raw materials on the protein content of the samples showed that increased inclusion of cornstarch decreased the moisture content of the samples. At the same time, millet and soybean addition positively affected the flour's protein content. The R^2-adjusted was 99.85%, showing that the effect was eliminated from the regression equation: ($PC = -1.41X_1 + 0.0275X_2 + 1.8225X_3 - 0.17X_1X_2 - 0.585X_1X_3 - 0.0925X_2X_3 - 0.0105X_1X_2X_3$). However, the interaction effects of the variables harmed the protein content of the custard produced. It implied that the interaction effect of increased addition of the entire variable (millet flour, cornstarch, and Soybean) would significantly reduce the protein content of the manufactured products ($p < 0.05$).

Meanwhile, cornstarch and millet flour inclusion negatively influenced the fat content of the custard. The effect of adding cornstarch and millet flour was insignificant ($p > 0.05$). Thus, the negative influence of cornstarch and millet flour addition could be a chance effect. There was, however, a significant ($p < 0.05$) positive effect of cornstarch- soybean flour interaction. In contrast, all the other interaction effects were not significant ($p > 0.05$) and were all positively correlated, except the interaction effect of the three variables, which was negatively correlated. The protein content varied significantly ($p < 0.05$) among all formulations. Higher soybean flour mixes produce custards with more protein. Ikegwu., *et al.* [8] reported that soybeans are good protein sources. Recent studies have shown that fermentation increases the crude protein content of pearl millet flour [21]. Meanwhile, increased protein content resulted from the increased addition of defatted soybean flour-enriched products with soy flour [22].

Ikegwu., *et al*. [8] reported that custard formulations prepared with higher amounts of soybean flour had more proteins than blends containing less. The decrease in fat content of the formulations could result from sufficient oil extraction from the soybean flour during the defatting process. However, soybean had been reported as a good source of fat (Kim., *et al.* 2021). Consequently, the low-fat content and the effect of sufficient oil extraction during defatting could have contributed to the exhibition of low peak viscosities in the samples with increased substitution of defatted soybeans. The significant changes ($p < 0.05$) in sample fat content for the formulated products could be an added advantage for individuals who demand low-fat food products. In Australia, the fat content of custard ranged between 0.9 and 3.1g.

Moreover, it could be deduced from the regression model that there was a significant effect ($p < 0.05$) of the increased inclusion of the variables on the sample fat content. Still, the impact of these variables was weak and could not be substantiated as the R-squared value was 76.89%, while the R-adjusted was 56.67%. The regression equation are as shown: ($FC = -0.3807X_1 - 0.2090X_2 + 0.0815X_3 + 0.031X_1X_2 + 0.8415X_1X_3 + 0.0148X_2X_3 - 0.2302X_1X_2X_3$).

However, the product's fat content was lower than the commercial custard sample which was 0.82%. As a building agent that reduces constipation and cardiovascular disease, fat is required in nutrition. It also slows digestion for the body's adequate absorption of nutrients from our food. Thus, it can also improve the heart's health by lowering blood cholesterol. Therefore, the result obtained was essential for further studies aimed at enhancing the fat content of custard to meet the requirement for commercial production or legal labeling and thus, serve as a vehicle for combating nutritional imbalance in the population.

The ash and fiber contents of the formulations showed that some samples varied significantly ($p < 0.05$). The fiber and ash contents of the formulations increased as the level of soybean flour inclusion increased. However, results showed that the ash content of sample ratios 100:10:5, 100:30:10 and 100:30:10 differed significantly from samples ratios 70:10:5, 70:30:5 and 100:10:5. It could be deduced that sample ratios 70:30:10 which had the highest ash content. The fiber content of formulated samples was not significantly different ($p > 0.05$), but they differed significantly ($p < 0.05$) from the control sample. Therefore, it could be inferred that the control sample was particularly the highest ($p < 0.05$) in the fiber content.

The influence of the fiber content was correlated. Regression analysis showed that the cornstarch, cornstarch-millet flour interaction, cornstarch-soybean interaction, and the interaction of cornstarch, millet, and Soybean all negatively influenced the fiber content of the samples. In contrast, millet flour, Soybean, and millet flour-soybean interaction were positively correlated. Assertively, the cornstarch, millet flour, and soybean flour do not have any significant effect on the custard samples as represented by the regression equation ($F_1C = -0.03425X_1 + 0.04375X_2 + 0.03075X_3 - 0.026X_1X_2 - 0.0475X_1X_3 + 0.02X_2X_3 - 0.04025X_1X_2X_3$).

The result of the regression analysis showed that the R-squared value was 51.34%, which was significant ($p < 0.05$). However, the R-adjusted value of 8.76% inferred that the considerable effect could not have significantly ($p < 0.05$) influenced the fiber content of the samples. The regression analysis of the raw material influence on the sample ash content showed that the variables had a negative correlation to the ash content of the samples. The increased addition of raw materials decreased the ash content of the formulated custard. The quadratic term was also negatively correlated with the ash content, but the interaction of millet flour and defatted soybean flour positively influenced the ash content of the custard samples. The fitted regression equation can be used to explain the model with an R-squared value of 99.95% and an R-square adjusted 99.40%. The equation of the fit for the variables is as shown:

$(Ash = 4.40 - 0.0077X_1 - 0.0498X_2 - 0.619X_3 - 0.000217X_1X_2 + 0.00497X_1X_3 + 0.03343X_1X_3 - 0.000293X_1X_2X_3)$.

As the amount of soybean flour increased, the formulation carbohydrate content fell. It showed that soybeans are low in carbohydrates [23]. Also, Ma., *et al.* [224] reported that fermentation lowered the carbohydrate while roasting and germination of Soybean increased the carbohydrate level, thereby causing an increase[a] in the energy density of flour. The pasting of custards depends heavily on starch concentration. Thus, custard made from flours with varied carbohydrate content may need quality standards. Owais., *et al.* [25] claimed that starch affects gelatinization temperature, cooked starch swelling capacity, structure, and content. The influence of the variables on the carbohydrate content was correlated. The regression analysis showed that cornstarch, cornstarch-millet flour, defatted soybean flour, and millet flour-defatted soybean flour all negatively influenced the carbohydrate content. In contrast, the cornstarch, millet flour, and defatted soybean flour were positively correlated. The quadratic term was positively associated with the carbohydrate content of the custard with an R-squared of 100% and an R-square adjusted 100%. Thus, the fitted regression equation can be used to explain the model. The effect of the different raw materials inclusion on the carbohydrate content by adding soybean flour to the custard product resulted in significant ($p < 0.05$) but not significant ($p > 0.05$) results. Thus, the increased carbohydrate content of sample 100:30:10 formulation could be attributed to the chance effect. The equation could represent the effect of the inclusions on the carbohydrate content of custard $(CHO = 67.490 + 0.21000X_1 + 0.86150X_2 + 0.9953X_3 - 0.007150X_1X_2 - 0.013333X_1X_3 - 0.138833X_2X_3 + 0.001203X_1X_2X_3)$.

Vitamin content of custard

Vitamins must be taken from the diet because the body cannot produce them sufficiently [26]. The regulatory bodies have recently passed legislation to add vitamin A to various foods due to poor vision caused by vitamin A deficiency. Thus, salt was employed to get vitamins to the poorest. The micronutrients from maize, millet, and soybean flours did not affect custard production, but it alleviated micronutrient insufficiency in the population. This study examined the nutritional content of custard flour. Vitamin A content varied substantially ($p < 0.05$) between samples, with 100:30:10 having the highest content, 70:10:5, 100:10:10, and the control sample having the lowest. Vitamin composition (mg/100g) of flour from maize-millet composite enriched with Soybean is shown (Table 3).

WHO/FAO advised adding vitamin A palmitate to commercial flour to prevent micronutrient shortages. With more flour per person each day, this quantity decreases. For flour over 300 g/day, 1.0 ppm is needed. Water-soluble vitamin B1 acts as a co-enzyme to oxidize glucose to produce ATP [27]. Vitamin B1 deficiency causes 'beriberi'. Vitamins are in all cereal grains (especially the bran and germ). Table 3 indicates a substantial increase ($p < 0.05$) in vitamin B1 levels in the samples. The sample control showed low vitamin B1 compared to the most significant sample ratio, 100:10:10, and the lowest, 70:30:5. Significant vitamin B2 enhancements ($p < 0.05$) were observed in sample ratios 70:10:5 and 70:30:10. This significant increase ($p < 0.05$) may be due to the chemical composition of the flours utilized in composite flour formulation.

Sample Ratio C:M:S	Vitamin A (IU)	Vitamin B_1 (mg/kg)	Vitamin B_2 (mg/kg)
70:10:5	$1391.08^{a} \pm 1.43$	$5.64^{e} \pm$ o.51	$0.37^{cd} \pm 0.00$
70:30:5	$383.00^{e} \pm 0.11$	$1.64^{f} \pm 1.92$	$0.10^{e} \pm 0.00$
70:30:10	$340.88^{g} \pm 0.63$	$12.02^{c} \pm 0.02$	$0.90^{ab} \pm 0.00$
100:10:10	$1913.94^{a} \pm 0.64$	$14.97^{a} \pm 0.05$	$1.03^{a} \pm 0.00$
10:100:5	$241.13^{i} \pm 0.01$	$9.02^{d} \pm 0.03$	$0.25^{de} \pm 0.28$
70:10:10	$296.91^{h} \pm 1.36$	$8.02^{d} \pm 0.03$	$0.18^{de} \pm 0.00$

100:30:10	354.12[f] ± 0.03	14.01[ab] ± 0.02	0.79[b] ± 0.00
100:30:5	411.34[d] ± 0.02	4.99[e] ± 0.01	0.34[cd] ± 0.00
Check	1318.88[c] ± 1.41	12.99[bc] ± 0.01	0.53[c] ± 0.00

Table 3: *Vitamin composition (mg/100g) of flour from maize-millet composite enriched with soybean.*

**Check = Commercial Custard Product.*

C = Cornstarch; M = Millet Flour; S = Defatted Soybean Flour.

A regression study revealed a substantial ($p < 0.05$) correlation between factors and vitamin content in cornstarch-enriched soybean custard samples. Cornstarch and millet flour lower vitamin A concentration, while soybeans enhance it. The interaction effects were unfavorable except for cornstarch-millet flour, which increased vitamin A content. Furthermore, the quadratic effect was positively correlated with the vitamin A content of the custard represented by (Vit. A = $-198.1X_1 - 631.5X_2 + 666.9X_3 - 70X_1X_3 - 673X_2X_3 + 120.5X_1X_2X_3$). A substantial effect of the variables was observed with an R-square value of 100% and an R-square adjusted value of 100% ($p < 0.05$). Additionally, the variables significantly affected the vitamin B_1 levels of custard samples. Cornstarch had no significant effect ($p > 0.05$), while millet-soybean flour increased vitamin B_1 levels. Cornstarch and soybean flour negatively affected vitamin B_1 levels, although cornstarch, millet, and soybean flour were positively linked. The quadratic term was favorably linked with custard vitamin B_1 concentration with an R-squared value of 98.71 percent and an adjusted 97.59 percent. The equation of fit for the variables is as shown (Vit.$B_1 = -0.229X_1 + 1.944X_2 + 0.744X_1X_2 - 5.434X_1X_3 + 0.769X_2X_3 + 2.919X_1X_2X_3$).

Cornstarch had a substantial negative correlation with the single effect term ($p < 0.05$). Conversely, millet and soybean flour increased vitamin B_2 levels. Except for the negatively linked cornstarch-soybean flour interaction, all quadratic and exponential variables favorably increased vitamin B_2 content. Including different raw materials significantly affected vitamin B_2 content in samples ($p < 0.05$), with an R-square value of 95.62 percent and an adjusted R-square of 91.78 percent. Corn starch had a substantial negative correlation with the single effect term ($p < 0.05$). Conversely, millet and soybean flour increased vitamin B_2 levels. Except for the negatively linked cornstarch-soybean flour interaction, all quadratic and exponential variables favorably increased vitamin B_2 content. Including different raw materials significantly affected vitamin B_2 content in samples ($p < 0.05$), with an R-square value of 95.62 percent and an adjusted R-square of 91.78 percent. Corn starch had a substantial negative correlation with the single effect term ($p < 0.05$). Conversely, millet and soybean flour increased vitamin B_2 levels. Except for the negatively linked cornstarch-soybean flour interaction, all quadratic and exponential variables favorably increased vitamin B_2 content. Including different raw materials significantly affected vitamin B_2 content in samples ($p < 0.05$), with an R-square value of 95.62 percent and an adjusted R-square of 91.78 percent. Corn starch had a substantial negative correlation with the single effect term ($p < 0.05$). Conversely, millet and soybean flour increased vitamin B2 levels. Except for the negatively linked cornstarch-soybean flour interaction, all quadratic and exponential variables favorably increased vitamin B= content. Including different raw materials significantly affected vitamin B_2 content in samples ($p < 0.05$), with an R-square value of 95.62 percent and an adjusted R-square of 91.78 percent. Corn starch had a substantial negative correlation with the single effect term ($p < 0.05$). Conversely, millet and soybean flour increased vitamin B_2 levels. Except for the negatively linked cornstarch-soybean flour interaction, all quadratic and exponential variables favorably increased vitamin B_2 content. Including different raw materials significantly affected vitamin B_2 content in samples ($p < 0.05$), with an R-square value of 95.62 percent and an adjusted R-square of 91.78 percent. Corn starch had a substantial negative correlation with the single effect term ($p < 0.05$). Conversely, millet and soybean flour increased vitamin B_2 levels. Except for the negatively linked cornstarch-soybean flour interaction, all quadratic and exponential variables favorably increased vitamin B_2 content. Including different raw materials significantly affected vitamin B_2 content in samples ($p < 0.05$), with an R-square value of 95.62 percent and an adjusted R-square of 91.78 percent. The equation could represent the effect of the inclusions on the vitamin B_2 content of custard: (Vit.B2 = $-0.14259X_1 + 0.11709X_2 + 0.55101X_3 + 0.11701X_1X_2 - 0.13391X_1X_3 + 0.02941X_2X_3 + 0.2674X_1X_2X_3$).

Influence of cornstarch, millet flour and soybean on the mineral content of custard

Results indicate significant mineral differences ($p < 0.05$) in most samples. The commercial product (control) had the most calcium and iron. Producers may have fortified the commercial product to meet regulatory requirements, resulting in large calcium and iron increases. There were no significant variations ($p < 0.05$) in zinc content between samples with ratios of 70:10:5, 70:30:10, and 100:10:5. Although the sample ratios of 70:30:10 and 100:10:5 had the highest potassium content, they differed considerably ($p < 0.05$). Sample ratios 100:30:10 and 100:10:10 had the lowest potassium levels. Mineral Composition (Mg/100g) of Maize-Millet composite Flour Enriched with Soybean is shown in table 4.

Runs C:M:S	Ca (mg/100g)	Zn (mg/100g)	Fe (mg/100g)	K (mg/100g)
70:10:5	$4.59^{b} \pm 0.01$	$1.26^{c} \pm 0.01$	$1.19^{c} \pm 0.01$	$122.26^{g} \pm 0.01$
70:30:5	$3.86^{g} \pm 0.01$	$1.08^{f} \pm 0.01$	$1.06^{g} \pm 0.00$	$125.59^{d} \pm 0.01$
70:30:10	$4.06^{e} \pm 0.01$	$1.26^{c} \pm 0.01$	$1.23^{b} \pm 0.01$	$130.34^{b} \pm 0.01$
100:10:10	$3.65^{h} \pm 0.01$	$1.36^{a} \pm 0.01$	$1.09^{f} \pm 0.00$	$118.86^{h} \pm 0.01$
100:10:5	$4.29^{c} \pm 0.01$	$1.19^{d} \pm 0.01$	$1.14^{e} \pm 0.01$	$124.49^{f} \pm 0.01$
70:10:10	$3.96^{f} \pm 0.01$	$1.27^{c} \pm 0.00$	$1.07^{g} \pm 0.01$	$130.63^{a} \pm 0.01$
100:30:10	$4.13^{d} \pm 0.01$	$1.34^{b} \pm 0.01$	$1.16^{d} \pm 0.00$	$128.86^{c} \pm 0.01$
100:30:5	$3.48^{i} \pm 0.01$	$1.16^{e} \pm 0.01$	$1.24^{b} \pm 0.01$	$116.66^{i} \pm 0.01$
Check	$6.36^{a} \pm 0.01$	$0.57^{g} \pm 0.00$	$1.67^{a} \pm 0.01$	$125.54^{e} \pm 0.01$

Table 4: *Mineral composition (Mg/100g) of maize-millet composite flour enriched with soybean.*

**Check = Commercial Custard Product.*

C = Cornstarch; M = Millet Flour; S = Defatted Soybean Flour.

Functional properties

Functional characteristics are physical and chemical factors that affect protein behavior in food systems during storage, heating, processing and consumption [28]. The functional characteristics of custard products were examined in table 5. Samples with lower gelation concentrations showed significant differences ($p < 0.05$). The commercial product (control) was not statistically different ($p < 0.05$) from other samples, ranking second with ratios of 70:10:5 and 70:30:5. Samples with lower gelation concentrations showed significant differences ($p < 0.05$). The commercial product (control) was not statistically different ($p < 0.05$) from other samples, ranking second with ratios of 70:10:5 and 70:30:5. Bulk density is a measure of the heaviness of flour. Bulk density is an important parameter that determines the ease of handling during transportation and processing [29]. The custard formulation had bulk densities of 0.57 - 0.89 g/ml. The sample Rc9 has the highest bulk density (0.89 percent) and a significant increase ($p < 0.05$) compared to other samples. Fortificants used during production may explain the commercial custard's high bulk density. Sample ratios 70:10:5 and 100:10:10 exhibited the lowest bulk density at 0.57 g/ml.

Sample Ratio C:M:S	Least Gelation (%)	Bulk Density (g/cm^3)	Swelling Power (%)
70:10:5	$5.99^{a} \pm 0.01$	$0.57^{e} \pm 0.02$	$0.79^{f} \pm 0.01$
70:30:5	$4.02^{b} \pm 0.02$	$0.64^{c} \pm 0.01$	$86.07^{a} \pm 0.70$
70:30:10	$3.00^{b} \pm 0.01$	$0.69^{b} \pm 0.14$	$81.00^{b} \pm 1.41$
100:10:10	$6.01^{a} \pm 0.01$	$0.57^{ce} \pm 0.01$	$79.00^{c} \pm 0.71$
100:10:5	$4.02^{b} \pm 0.02$	$0.62^{d} \pm 0.02$	$74.98^{d} \pm 0.04$
70:10:10	$3.99^{b} \pm 0.01$	$0.59^{de} \pm 0.01$	$76.00^{d} \pm 0.71$
100:30:10	$3.99^{b} \pm 0.01$	$0.69^{b} \pm 0.01$	$72.96^{e} \pm 0.71$
100:30:5	$4.01^{b} \pm 0.01$	$0.64^{c} \pm 0.01$	$79.55^{bc} \pm 0.64$
*Check	$3.99^{b} \pm 0.01$	$0.89^{a} \pm 0.01$	$80.00^{bc} \pm 0.01$

Table 5: *Functional properties of the formulated custard powder.*

**Check = Commercial Custard Product.*

Food hydration is measured by swelling power. Swollen starch granules and their occluded water are weighed. Results indicate substantial differences (P < 0.05) in flour swelling power between samples. The swelling power was maximum in Rc2. The swelling power of Rc2 differed considerably (p < 0.05) from the control sample Rc9. Solubility is inversely related to proteins with high non-polar regions (residues). As soy flour was added, the swelling power dropped and was consistent [30]. The high swelling power of soy-fortified flour may suggest its applicability in noodle production [31]. This finding indicates that maize millet enhanced with soybean custard powder would be a valuable addition to soup recipes and a preferred option for producing thinner gruels.

Pasting properties

The amount of protein and lipids in the flour, the amylase level of the flour, and the processing methods all impact how well starch pastes [22]. Table 6 shows how soybean flour enrichment affects custard powder pasting and function. The results showed significant differences in peak, final, and trough viscosity among enrichment levels (p ≤ 0.05). These differences in the starchy products could be attributed to the differences in the substitution levels of the different flours. It could be deduced that the peak, holding, and final viscosity for Rc2 were 251.83, 220.08, and 309.25 RVU, respectively. This result differed from Rc3, whose peak, holding, and absolute viscosity were 108.58, 67.67, and 170.08 RVU, respectively. Sample Rc2 comprised 30% millet, 70% cornstarch, and 10% soybean flour. Studies have shown that an increase in soybean flour increased the fat content, while adding cornstarch and millet had no effect [32]. However, protein and fat have been implicated in the pasting properties of custard products [33]. The composite flours with higher fat and protein content had higher peak viscosities, supporting Arukwe., *et al.* [34] claimed that free fatty acid, one of the most crucial lipid components, may cause peak viscosity and delay pasting time during gelatinization.

Pasting properties	70:10:5	70:30:5	70:30:10	100:10:10	100:10:5	70:10:1	100:30:10	100:30:5	Checks*
Peak Viscosity (RVU)	221.42 ± 0.23	251.83 ± 0.10	108.58 ± 0.10	133.56 ± 0.16	128.58 ± 0.05	161.92 ± 0.03	164.92 ± 0.02	175.67 ± 0.01	210.67 ± 0.11
Trough (RVU)	157.00 ± 0.15	220.08 ± 0.05	67.67 ± 0.03	85.08 ± 0.12	106.42 ± 0.11	100.67 ± 0.02	100.33 ± 0.01	101.08 ± 0.04	144.33 ± 0.12
Breakdown (RVU)	64.42 ± 0.11	31.75 ± 0.03	40.91 ± 0.02	48.48 ± 0.02	22.16 ± 0.08	61.25 ± 0.01	64.59 ± 0.04	74.59 ± 0.07	66.34 ± 0.03
Final viscosity (RVU)	237.8 ± 0.20	309.25 ± 0.12	170.08 ± 0.05	145.25 ± 0.15	229.33 ± 0.16	232.92 ± 0.06	227.33 ± 0.10	160.58 ± 0.13	231.42 ± 0.02
Setback (RVU)	15.66 ± 0.08	57.42 ± 0.09	61.50 ± 0.21	11.69 ± 0.05	100.75 ± 0.02	71.00 ± 0.03	62.41 ± 0.04	15.09 ± 0.01	20.75 ± 0.01
Peak Time (min)	6.35 ± 0.10	6.45 ± 0.04	6.55 ± 0.06	6.75 ± 0.07	6.63 ± 0.01	6.25 ± 0.02	6.44 ± 0.01	6.37 ± 0.03	6.55 ± 0.03
Pasting Temperature (°C)	92.58 ± 0.13	93.65 ± 0.07	93.55 ± 0.01	93.65 ± 0.11	93.48 ± 0.04	93.67 ± 0.10	93.28 ± 0.02	93.44 ± 0.05	93.85 ± 0.03

Table 6: *Pasting properties of formulated custard powder.*

Also, the protein content of the sample ratio Rc2 was 4.82%, while the fat content was 0.02%. Thus, increased soybean addition on the formulated custard was likely responsible for the increase in peak viscosity of sample ratio Rc2. Peak viscosity is the maximal resistance of heated flour and water slurry to pin mixing and represents the ideal starch development stage [35]. Amylose solubilization and leaching caused inflated hydrated aggregates and dissolved molecules to disperse viciously. Higher peak viscosity indicates starch with more slurry reaching the pins during stirring, resulting in less enzyme activity and a better product. Poor setback values imply low starch retrogradation and syneresis, while high breakdown follows peak viscosity and is related to starch swelling [36].

Denatured proteins promote the matrix structure and inhibit the thixotropic nature of wheat starch, resulting in the lowest breakdown viscosity and best thermo-stability for Rc5. The custard also has rheopectic qualities at a constant shear rate due to the starch structure amylopectin and amylose realignment to stabilize. Sample Rc8 showed the lowest setback viscosity, possibly due to the flour's lower amylase level, indicating a decreased retrograde propensity. The breakdown viscosity dropped from 31.75 to 74.59 RVU ($p < 0.05$) as the percentage of soybeans grew from 0 to 10%. The setback refers to the variation in ultimate viscosity between paste viscosity and trough viscosity [37]. The stability of a paste after cooking is gauged by its setback. This is the stage at which, to a greater or lesser extent, mixed re-association between the starch molecules occurs during cooking. It consequently influences the starch molecules' retrogradation or reorganization [38]. Starch retrogradation is a process in which the starch chains (amylose and amylopectin) in the gelatinized paste interact on cooling after heating, forming a more ordered structure of molecular interactions [39]. Also, the negative value (-15.09) in the setback of sample Rc8 showed low amylose content. Hence, it is a good sign of retrogradation stability (realignment of amylose and amylopectin molecules). The custard enhanced with 10% and 5%, respectively, had the most significant peak time values of 6.75 and 6.63 minutes. Boonkor., *et al*. [40], reported that starch paste's final viscosity indicates its capacity to form pastes or gels after cooling, and a high breakdown value usually results in less stability. After cooling, soybean-free samples will be less stable. Peak viscosity frequently indicates product quality. Peak temperature is where viscosity initially increases by 2 RVU over 20 seconds. It shows the temperature needed to cook flour beyond gelatinization at about the same temperature. There is no significant influence of soy-flour enrichment on pasting temperature ($p > 0.05$). The current investigation showed that samples could be cooked past gelatinization at almost the same temperature. Breakdown viscosity measures granule or paste breakdown during the viscosity test holding period [41]. This fact had also been established by Bai., *et al*. [42], who found that lower breakdown viscosity increases paste stability. Uzodinma., *et al*. [43] reported increased breakdown viscosity, lower sample heat, and shear stress resistance during cooking. This study reveals that maize-millet-enhanced custard with more soy flour can tolerate heating and shear stress.

Sensory acceptability of custard gruel

The custard samples were subjected to statistical analysis. The results obtained from the questionnaire were analyzed using Analysis of Variance and separated using Duncan's separation. Rc2 was the best in color, taste, flavor, texture, and acceptability. However, sample Rc2 was compared favorably with the control sample (Checkers custard). Furthermore, no significant differences ($P < 0.05$) between the sample Rc2 and the control sample Rc9 regarding color and texture. Nevertheless, differences ($P < 0.05$) observed in samples Rc2 and Rc9 in terms of taste, flavor, and overall acceptability were not highly significant ($p < 0.05$).

Regarding taste and flavor, samples Rc3, Rc5, and Rc6 were ranked the least by the consumers. Also, in the absence of either the Rc2 or the control sample (Rc9), the consumers may consider any of the other samples, although the consumers ranked them in the order of acceptability as follows: Rc2, Rc9, Rc4, Rc1, and others. Thus, this is evidence that the formulated custard powder can be served in place of the commercial custard product.

Runs	Color	Taste	Flavor	Texture	Overall Acceptability
70:10:5	$6.95^{ab} \pm 1.64$	$6.45^{abc} \pm 2.04$	$6.25^{abc} \pm 1.74$	$6.90^{ab} \pm 1.48$	$6.90^{abc} \pm 1.48$
70:30:5	$7.70^{a} \pm 1.17$	$7.70^{a} \pm 1.08$	$7.60^{a} \pm 1.00$	$7.70^{a} \pm 1.60$	$7.70^{a} \pm 0.98$
70:30:10	$6.30^{b} \pm 1.22$	$5.90^{c} \pm 1.83$	$5.95^{c} \pm 1.88$	$6.65^{ab} \pm 1.63$	$6.10^{c} \pm 1.68$
100:10:10	$7.00^{ab} \pm 1.21$	$6.55^{abc} \pm 1.64$	$6.45^{abc} \pm 1.99$	$6.65^{ab} \pm 1.87$	$6.90^{abc} \pm 1.52$
100:10:5	$6.10^{b} \pm 1.97$	$5.50^{c} \pm 2.16$	$6.05^{bc} \pm 2.26$	$5.85^{b} \pm 2.46$	$6.15^{c} \pm 2.13$
70:10:10	$6.70^{ab} \pm 1.42$	$6.85^{c} \pm 1.66$	$5.90^{c} \pm 1.17$	$6.20^{a} \pm 1.74$	$5.85^{c} \pm 1.50$
100:30:10	$6.15^{b} \pm 2.13$	$6.15^{bc} \pm 2.11$	$5.85^{c} \pm 2.03$	$6.45^{a} \pm 2.09$	$6.45^{c} \pm 2.16$
100:30:5	$6.35^{b} \pm 1.57$	$6.05^{bc} \pm 2.60$	$6.45^{abc} \pm 1.99$	$6.95^{ab} \pm 2.14$	$6.50^{bc} \pm 2.04$
Checks*	$7.65^{a} \pm 0.99$	$7.30^{ab} \pm 2.00$	$7.30^{ab} \pm 2.06$	$7.65^{a} \pm 1.46$	$7.65^{ab} \pm 1.39$

Table 7: *Means sensory attributes of gruel prepared from formulated custard powder and control.*

Values are mean ± SD (n = 3). Means with same letters are not significantly different (p < 0.05). Samples = (Cornstarch: Millet flour: Soybean flour). Checks, a commercial custard product as the control.*

Conclusion

The research observed that the sample with the formulation 70:30:5 (maize: millet: Soybean) was the best, which ranked first (7.70), followed by results (7.65), while the sample with the formulation 70:10:10 ranked least (5.85). The swelling power of the 70:30:5 was also observed to be the highest (86.07%), followed by the commercial product (80.00%), while the sample formulated with the ratio 70:10:5 ranked least (0.79%). It is therefore concluded that commercial custard manufacturers should prepare products with the blends 70:30:5 for improved nutrition, swelling power, rheological and economic considerations. However, there is a need to explore other means to improve the calcium content of the sample to compare with the commercial products.

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Data Availability Statement

The data presented in this study are available on request from the corresponding author. The data are not publicly available due to privacy.

Conflicts of Interest

The authors declare no conflict of interest.

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